C-3.1 Predict the type of bonding (ionic or covalent) and the shape of simple compounds by using Lewis dot structures and oxidation numbers.

Revised Taxonomy Level 2.5-B Infer (predict) conceptual understanding

In Physical Science students

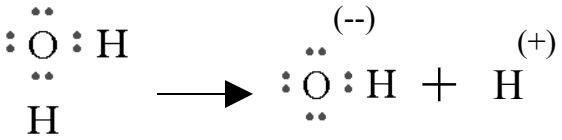
- Explain the role of bonding in achieving chemical stability. (PS-4.1)
- Explain how the process of covalent bonding provides chemical stability through the sharing of electrons. (PS-4.2)
- Illustrate the fact that ions attract ions of opposite charge from all directions and form crystal lattices. (PS-4.3)
- Classify compounds as crystalline (containing ionic bonds) or molecular (containing covalent bonds) based on whether their outer electrons are transferred or shared. (PS-4.4)
- Predict the ratio by which the representative elements combine to form binary ionic compounds, and represent that ratio in a chemical formula. (PS-4.5)

It is essential for students to

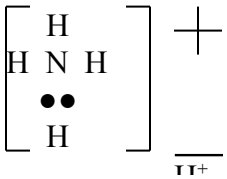
- Understand that the structure of molecules is the result of nonmetals sharing electrons in order to form stable outer-energy-level configuration. (covalent bonds)
  - Understand that because orbitals in the outer energy level of an atom are most stable when they contain two electrons, a covalent bond is likely to form between two elements which will both achieve the status of a full orbital in the outer energy level.
    - Covalent bonds are common between two elements, each having one or more orbitals in the outer energy level containing only one electron.
  - Understand how single, double, and triple bonds are formed.
  - Understand that the "s" and "p" orbitals in the outer energy level of each atom provide four possible bonding sites (except for the elements which achieve He structure)
  - Understand the 3-dimensional nature of molecules (tetrahedral bonding site structure)
  - Explain the shape of simple molecules such as water and carbon dioxide using VESPR
  - Draw Lewis dot structures for simple molecules
- Understand that crystalline structure is the result of the ionic bonding of positive and negative ions, forming a neutral compound.
  - The sum of the oxidation numbers in the formula of any neutral compound is zero
  - Understand that metallic atoms can form positive monatomic ions by losing electrons in order to achieve a stable outer energy level electron structure
  - Understand that nonmetal atoms can form negative monatomic ions by gaining electrons in order to achieve a stable outer energy level electron structure
  - Know that the oxidation number of a monoatomic ion is equal to its charge
  - Know the oxidation number of the monoatomic ions formed from elements in the following groups of the periodic table
    - Group 1, +1
    - Group 2, +2
    - Group 16, -2
    - Group 17, -1
    - Understand that some covalently bonded groups of atoms (similar in structure to molecules) act like single atoms in forming ions. These charged groups of covalently

bonded atoms are called polyatomic (many-atomed) ions and may be positive or negative.

- This most frequently occurs when a molecule loses one or more hydrogen ions (H^+), leaving the species negatively charged, such as the disassociation of water into a hydroxide ion (OH^-) and a hydrogen ion (H^+)



- The ammonium ion is formed when a molecule of ammonia, (NH_3), combines with a hydrogen ion, (H^+), resulting in a positively charged species. (NH_4^+)



- Such a species is called a polyatomic ion
- Understand that the oxidation number of a polyatomic ion is equal to its charge
- Understand that polyatomic ions react exactly the same as monoatomic ions in chemical reactions
- Use Lewis dot formulas to demonstrate ionic bonding

Assessment Guidelines

The objective of this indicator is for students to <u>infer (predict)</u> the type of bond and the shape of a simple compound (draw a logical conclusion) based on the outer energy level electron structure of the component elements. As this is <u>conceptual knowledge</u> (knowledge of the interrelationships among the basic elements within a large structure that enable them to function together) the primary focus of assessment should be to show that students can use knowledge of chemical stability and the relationship between an element's position on the periodic table and outers-level electron arrangement to predict whether an atom will gain, lose or share electrons, and how many electrons will be involved. In addition, students should have an understanding that many atomic properties are a result of an atoms tendency to gain or lose electrons.

C-3.2 Interpret the names and formulas for ionic and covalent compounds.

Revised Taxonomy Level 2.1 B Interpreting conceptual knowledge

In Physical Science Students

- Predict the ratio by which the representative elements combine to form binary ionic compounds, and represent that ratio in a chemical formula. (PS-4.5)

It is essential for students to

- Name and write the chemical formulas for binary molecular compounds
- Name and write the chemical formulas for ionic compounds including those that contain common polyatomic ions
- Identify substances as molecular or ionic compounds
- Compare molecular and ionic compounds according to their properties
- Differentiate and write molecular formulas, empirical formulas and structural formulas

Assessment

Since the verb for this indicator is interpret (represent) the major focus of assessment will be for students to "change from one form of representation to another". In this case, write the name of a chemical compound when given the formula, or write the formula when given the name. As this indicator is classified as conceptual knowledge, it is vital that students understand the protocol for naming and writing the formulas for chemical substances and can apply their knowledge of chemical nomenclature to any chemical formula or name of a chemical compound or substance.

C-3.3 Explain how the types of intermolecular forces present in a compound affect the physical properties of compounds (including polarity and molecular shape).

Revised Taxonomy Levels 2.7 B Explain conceptual knowledge

Students did not study this concept in physical science

It is essential for students to

- Understand that ionic bond and covalent bond are relative terms and that most bonds that we characterize as ionic or covalent actually have a character that lies somewhere between 100% ionic and 100% covalent
  - Bonds between active metals and active nonmetals are characterized by a high degree of ionic character because electron transferred is virtually complete
    - Because ionic bonds are very strong, substances with ionic bonds usually have high melting and boiling points
  - Bonds between identical non metals (diatomic compounds) are characterized by zero percent ionic character because electrons are shared equally.
  - Bonds between other substances (such as the bond between oxygen and hydrogen) have an intermediate nature; the shared electrons are not shared equitably but spend more time with whichever atom is more electronegative.
    - The atom with the stronger attraction for electrons becomes partially negatively charged
    - The atom with the lower electronegativity value becomes partially positively charged
    - Covalent bonds that do not share the electrons equally are called polar covalent bonds
    - Covalent bonds that do share the electrons equally are called non-polar covalent bonds
    - If the polar bonds in a molecule are all alike, the polarity of the molecule as a whole depends only on the arrangement in space of the bonds (water molecules are polar due to bent structure)
    - Polar molecules are attracted to one another, but the attraction is not a chemical bond so it is broken easily. These substances usually have moderate melting and boiling points
    - Polar molecules are attracted to one another and to ionic substances as well

Assessment

The verb, explain means that the major focus of assessment should be for students to "construct a cause and effect model". In this case, assessments will ensure that students can model how intermolecular forces affect the properties of a substance. Because the indicator is written as conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students can construct a cause and effect statement relating how intermolecular forces which are determined by the type of bonding within a substance, affect the properties of the substance.

C-3.4 Explain the unique bonding characteristics of carbon that have resulted in the formation of a large variety of organic structures.

Revised Taxonomy Levels 2.7 B Explain conceptual knowledge

Students did not study this concept in physical science

It is essential for students to

- Understand bonding in the allotropic forms of carbon, diamond and graphite
- Describe hybridization (sp^3) of simple molecules
- Understand how the capacity to form four covalent bonds results in several bonding possibilities for carbon, including
  - Single, double, and triple bonds
  - Ring structures
  - Covalent network

Assessment

The verb, explain means that the major focus of assessment should be for students to "construct a cause and effect model". In this case, assessments will ensure that students can model sp^3 hybridization for many possible bonding configurations for carbon. Because the indicator is written as conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students can construct a cause and effect statement relating how sp^3 hybridization allows for four lone electrons and therefore many possible bonding configurations.

C-3.5 Illustrate the structural formulas and names of simple hydrocarbons (including alkanes and their isomers and benzene rings).

Revised Taxonomy Level 2.2-B Exemplify (illustrate) conceptual knowledge

Students did not cover this standard in physical science

It is essential for students to

- Understand International Union of Pure and Applied Chemistry (IUPAC) organic nomenclature
- Name and write the formula for alkanes (up to 10-carbon), their isomers and benzene rings
- Draw the structural formulas for alkanes up to a 10-carbon chain

Assessment

The verb exemplify (illustrate) means to find a specific example or illustration of a concept or principle, therefore the major focus of assessment will be for students to give examples that show that they understand the organic nomenclature for organic alkanes and their isomers. Conceptual knowledge requires that students understand the interrelationships among the basic elements within a larger structure that enable them to function together, in this case, that students understand how the structure of the molecule determines its name.

The following five indicators (C-3.6-C3.10) should be selected as appropriate to a particular course for additional content and depth:

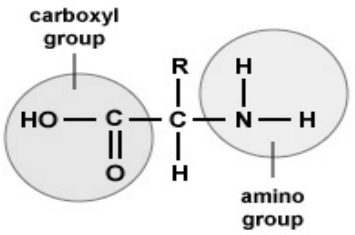
C-3.6 Identify the basic structure of common polymers (including proteins, nucleic acids, plastics, and starches). (additional content/depth)

Revised Taxonomy Level 1.1 B (Identify conceptual knowledge)

Students did not study this concept in physical science

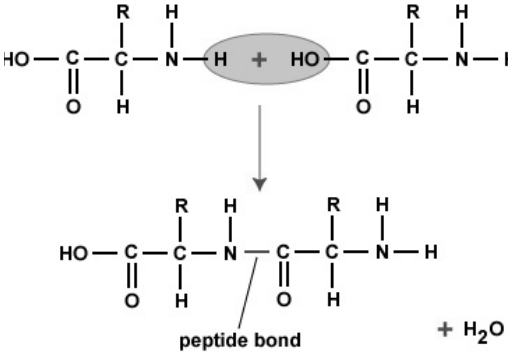
It is essential for students to

- Recognize the basic structure of a protein as that of a polymer composed of monomers of amino acids.
  - The basic structure of an amino acid is



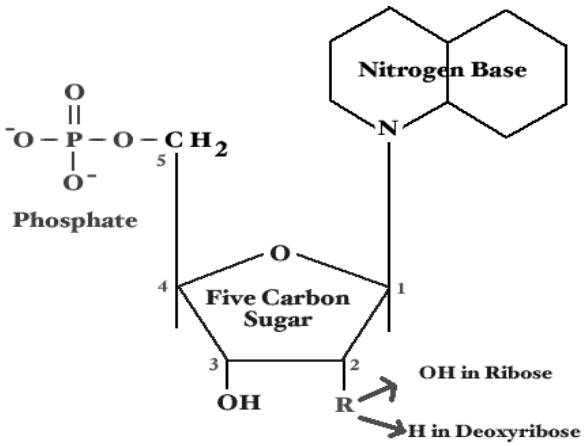
Amino Acid

  - Where "R" represents H, CH_3 or a more complex organic functional group
  - Understand that there are 20 amino acids commonly found in proteins, that differ with regard to the "R" group
  - Understand that peptide bonds are formed between the amino acids to form proteins



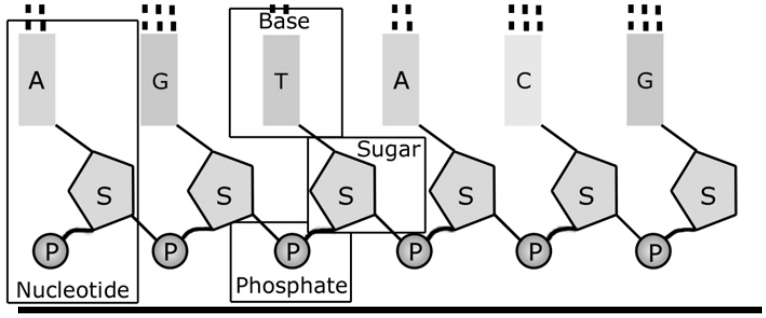
Protein

- Recognize the basic structure of a nucleic acid as that of a polymer composed of monomers of nucleotides.
  - The basic structure of a nucleotide is that of a



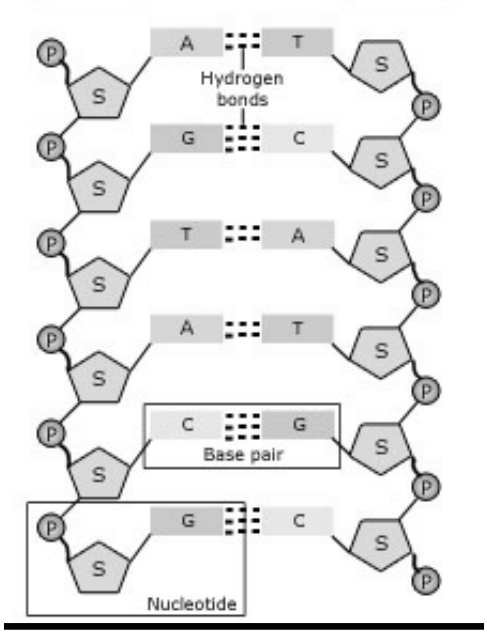
Nucleotide

- An organic functional group ("R") representing H, CH_3 or a more complex organic functional group
- Phosphate
- A five-carbon sugar
- A nitrogen base (the structure of the nitrogen base varies with different nucleic acids)
  - Uracil (U)
  - Cytosine (C)
  - Thymine (T)
  - Adenine (A)
  - Guanine (G)
- The nucleotides form the nucleic acid polymer by bonding between sugars and phosphates



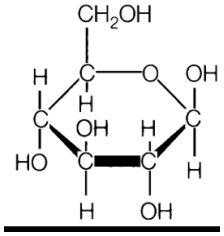
Single stranded DNA

- Duplication of the polymers result from bonding at the bases
  - T only bonds with A or U
  - G only bonds with

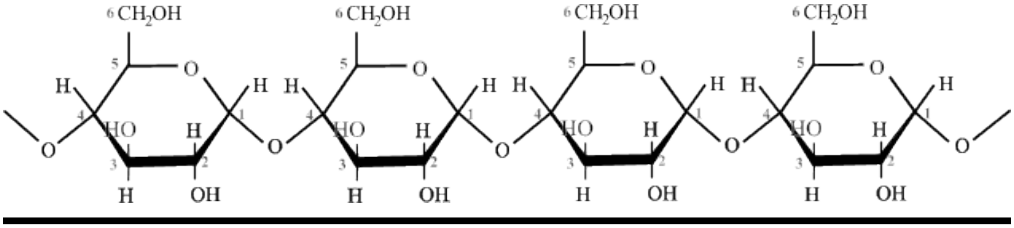


Double Stranded DNA

- Recognize the basic structure of carbohydrate as that of a polymer composed of monomers called monosaccharides (simple sugars).
  - Monosaccharides contain carbon hydrogen and oxygen in a ratio of 1:2:1 which gives an empirical formula of CH_2O
  - Starch is composed of monosaccarides of glucose



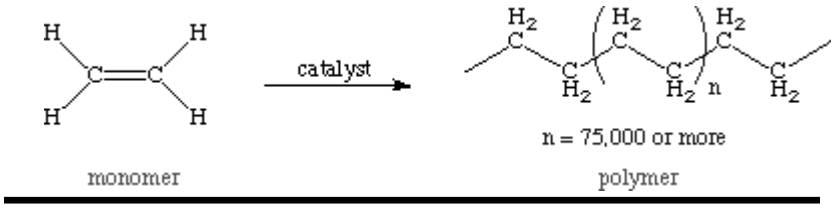
Glucose



Starch

- Understand that a plastic is a synthetic polymer (polymer prepared in the laboratory or industry) that is easily molded.
  - There are two types of plastic
    - Thermoplastics which soften or melt when heated
    - Thermosetting plastics which harden or set when heated and do not remelt

- Recognize the basic structure of a plastic as that of a polymer composed of monomers derived from petroleum
  - An example is polyethylene with monomers of ethylene



Ethylene **Polyethylene**

Assessment

As the verb for this indicator is recognize (identify), the major focus of assessment should be for students to "locate knowledge in long term memory that is consistent with presented material; in this case, for students to be able to identify the substances presented here as polymers, and to recall the general composition and the name of the monomers which compose them when presented with diagrams or descriptions of the substances. Conceptual knowledge requires that students understand the interrelationships among the basic elements within a larger structure that enable them to function together, in this case, that students know how the parts of each polymer come together to form the whole.

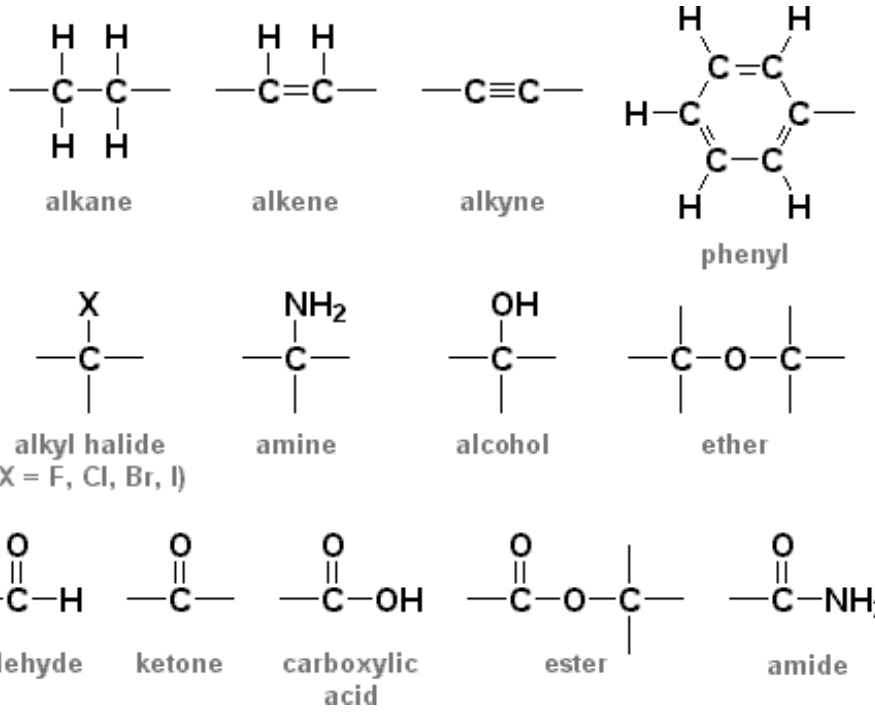
C-3.7 Classify organic compounds in terms of their functional group. (additional content/depth)

Revised Taxonomy Level 2.3 B (Classify conceptual knowledge)

This concept was not covered in physical science

It is essential for students to

- Name and draw structural formulas of alkenes, alkynes, benzene and cyclohexanes.
- Define the term functional group
- Recognize the following functional groups when presented with the structural formula of a compound
- Understand the rules of organic nomenclature as they apply to naming compounds which contain each of the following functional groups



Assessment

As the indicator states, the major focus of assessment is to classify organic substances based on the functional group as illustrated by a structural formula.

As the taxonomy verb is classify as opposed to distinguish, the assessment item should include all of the relevant information that is needed to make the distinction between categories, students should not have to pick out the relevant information.

As the indicator has a cognitive dimension of conceptual knowledge, assessment items will require that students understand each of these categories in terms of the "interrelationships among the basic elements within the category", in other words students must show that they understand the criteria for each category. Assessments will require that students can classify any given structural formula.

C-3.8 Explain the effect of electronegativity and ionization energy on the type of bonding in a molecule. (additional content/depth)

Revised Taxonomy Levels 2.7 B Explain conceptual knowledge

This topic was not addressed in physical science

It is essential for students to

- Infer relative electronegativity values for elements based on the element's position on the periodic table.
- Use a table of electronegativity values to assign values to elements represented in the structural formula of a substance.
- Determine the percent ionic character of a bond based on the electronegativity difference of the elements involved
- Understand how the electronegativity difference can be used to classify the type of bond in a substance
- Infer relative ionization energy values for elements based on the element's position on the periodic table.
- Use a table of ionization energy values to assign values to elements represented in the structural formula of a substance.
- Understand how the relative ionization energies of two elements can be used to predict the type of bonding that form between them.
- Interpret the polarity of a molecule based on its geometry bond type.

Assessment

The verb, explain means that the major focus of assessment should be for students to "construct a cause and effect model". In this case, assessments will ensure that students can model electronegativity values or ionization energy values to predict the type of bonds that will form between two elements. Because the indicator is written as conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students can construct a cause and effect statement relating how the atomic structure of the element dictates its electronegativity and ionization energy values and that the student can make judgments concerning bond formation based on a comparison of either of these values.

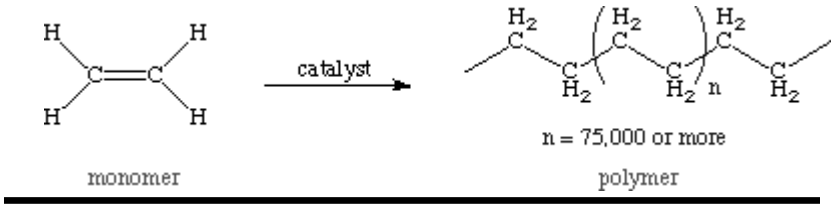
C-3.9 Classify polymerization reactions as addition or condensation (additional content/depth)

Revised Taxonomy Level 2.3 B (Classify conceptual knowledge)

Students did not address this topic in physical science

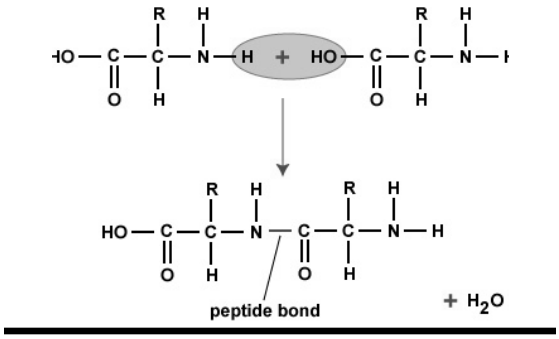
It is essential for students to

- Understand that an addition polymer is one which has been formed by chain addition reactions between monomers that contain a double bond.
  - For example, the polymerization of ethylene into polyethylene



Ethylene **Polyethylene**

- Understand that a condensation polymer is one which has been formed by two different parts of the same type of a molecule combining into long chains.
  - For example, the peptide bond in proteins



Protein formation from amino acids

Assessment

As the indicator states, the major focus of assessment is to classify polymers by the type of bonding. As the taxonomy verb is classify as opposed to distinguish, the assessment item should include all of the relevant information that is needed to make the distinction between categories, therefore, the bonding steps should be illustrated with structural formulas, diagrams or with verbal descriptions.

As the indicator has a cognitive dimension of conceptual knowledge, assessment items will require that students understand each of these categories in terms of the "interrelationships among the basic elements within the category", In other words students must show that they understand the criteria for each category.